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Original article

Relationship between autologous bone graft osteointegration and correction loss after antero-posterior spondylodesis of traumatic vertebral body fracture

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A B S T R A C T

Background: A common method to restore the sagittal alignment and stabilize the spinal column is a dorso-ventral spondylodesis. It is assumed that correction loss after posttraumatic spondylodesis results from inadequate incorporation of the autologous iliac crest graft.
Materials and methods: Retrospective documentation of patients with unstable vertebral body fractures of the thoracic or lumbar spine with concomitant rupture of at least one adjacent intervertebral disk who received surgical treatment at our institution from 2000 to 2006. Followed by analysis of the computer tomography documentation of a total of 142 patients with unstable vertebral body fracture stabilized by posterior internal fixator and anterior iliac crest spondylodesis.
Results: The following mean angle changes were derived from the second series of CT scans performed on average 283 days after anterior spondylodesis: vertebral wedge angle (VWA): 2.1°; segmental kyphotic angle: 4.9°; adjusted-SKA: 4.8°; sagittal index (SI): −0.04; segmental-scoliotic-angle (SSA): 0°; adjusted-SSA: 0°. Changes in VWA, both SKAs and SI postoperatively and prior to ME, were statistically significant ($P < 0.05$). The McAfee fusion assessment of the graft showed: full fusion: cranial 64%, caudal 47%; partial fusion: cranial 20.5%, caudal 29%; lysis: cranial 8.5%, caudal 17%; graft resorption: 7%. No correlation was found between the above-mentioned angle changes and fusions grade.
Discussion: The importance of radiological evidence of fusion deficiency is questionable, because the extent of fusion only has a minimal effect on correction loss.
Level of evidence: Level IV.

1. Introduction

The ambition of the treatment of thoracolumbar fracture should be the restoration of vertebral column and therefore the sagittal alignment. It may associate, depending on the type of fracture, decompression, reduction, graft and/or internal fixation, using a posterior, anterior or combined approach. Indications for an anterior approach weigh the pros and cons as well as the type of osteo-ligamentous lesion, degree of instability and patient's neurological status.

A common method to restore the sagittal alignment and stabilize the spinal column is a dorso-ventral spondylodesis. A vertebral fusion can be achieved with autologous, allogenic or xenogenic bone grafts, which are inserted between the vertebral bodies. Other materials and systems such as titanium cages are becoming more and more important, whereas spondylodesis with autologous tricortical bone graft represents the current clinical standard in many hospitals.

Despite the positive characteristics of autologous bone graft in terms of osteoinduction and osteoconduction [1,2], routine clinical practice sees a small number of patients who complain of persistent symptoms in the operated spinal segment after dorso-ventral spondylodesis. This figure can rise to 33% of all operated patients depending on the patient collective under investigation [3].

One of the numerous reasons for persistent symptoms after a dorso-ventral spondylodesis is a correction loss in reconstructions of the anterior spine column after trauma employing autologous iliac crest graft. This circumstance has been attributed to a lack of bone fusion, which is visible on the radiographs. In many cases, explantation of the posterior fixator is delayed by several months to await better graft consolidation in an effort to minimize the risk of secondary correction loss. It must however be said that exploratory

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investigation of the anterior column after iliac crest graft reconstruction has revealed that the radiological findings do not always reflect the in vivo situation [4].

For this reason, the present study was designed to examine the relationship between the CT-based radiological evidence of anterior column consolidation and correction loss with the internal fixator in situ.

2. Method

2.1. Study design and patient sample

Retrospective documentation of all patients with unstable vertebral body fractures of the thoracic or lumbar spine with concomitant rupture of at least one adjacent intervertebral disk who received surgical treatment at our institution from 2000 to 2006.

In that period, 208 patients (m:f 1.7:1; average age 41 years; range 15–81 years) with the above-mentioned injury pattern were treated. For 142 of the 208 patients, the CT scans available for analysis were a preoperative scan, a scan immediately after surgical stabilization and one taken shortly before explantation of the posterior instrumentation so that the data from this collective was sufficient for the purpose of this study. In terms of demographic data (age, sex, fracture site, fracture classification, neurological symptoms), there was no significant difference between the primary sample and the 142 patients selected. The CT-based classification of fractures, the manifestation of neurological deficits according to Frankel and fracture distribution across various sites are summarized in Tables 1–3.

2.2. Surgical procedure

All 142 patients were treated the same way; within the first few hours of injury open surgical stabilization was performed using posterior instrumentation without navigation (USS® with Schanz screws, Synthes, Germany; 2% mono-, 88% bi- and 10% multi-segmental). Depending on the extent of spinal canal stenosis and the neurological symptoms, decompression was performed by hemilaminectomy or laminectomy (64 of 142–45%). Diagnosis of vertebral disk rupture was made during the first operation by discography and the decision to perform mono- (104 of 142 – 73%) or bisegmental (38 of 142 – 27%) reconstruction of the anterior column was based on these findings. During the same hospital stay (on average 13 days after posterior stabilization), open anterior spondylodesis with tricortical iliac crest graft but without an additional implant was completed. Depending on fracture level, the approach was thoracotomy with incision of the pleura or lumbotomy without incision of the peritoneum. Graft was harvested from the anterior iliac crest in open technique.

Table 1
Fracture classification.

AO/OTA fracture classification		
	n	%
A2	2	1
A3	112	78
B1	5	4
B2	7	5
B3	2	1
C1	6	4
C2	7	5
C3	1	1
Total	142	100

Table 2
Incidence of neurological deficits.

Neurological deficit		
	n	%
Frankel A	2	1
Frankel B	3	2
Frankel C	3	2
Frankel D	8	6
Frankel E	126	88
Total	142	100

Table 3
Fracture localization.

Fracture localization		
	n	%
T6	1	1
T7	2	1
T8	2	1
T9	1	1
T12	24	17
L1	58	41
L2	23	16
L3	22	15
L4	7	5
L5	2	1
Total	142	100

2.3. Radiological analysis

CT scanning was performed with a Siemens device (Somatom Sensation 64®, 64-line configuration, ultra high isotropic resolution 0.24 mm; scan field <0.4 mm). J-Vision/DiAgnost software (TIANI Medgraph AG) was used for digital processing to create frontal and sagittal reconstruction of layers.

First, fractures were classified according to Magerl et al. based on the initial CT scans [5].

In order to assess correction loss, the following parameters were quantified at the three time points given above (preoperative, immediately after spondylodesis, and shortly before USS explantation) as described in the publication by Knop et al. [6]:

- vertebral wedge angle (VWA): the angle between the cranial and caudal plates of the fractured vertebra (positive angle indicates kyphotic posture);
- sagittal index (SI): quotient from the heights of the anterior and posterior margins;
- segmental kyphotic angle (SKA-1): angle between the caudal plate of the fractured vertebra and the cranial plate of the adjacent vertebra on the cranial side and the adjusted segmental kyphotic angle (SKA-2), which is the same as SKA-1 but additionally includes the cranial intervertebral disk. In the case of bisegmental spondylodeses, the SKA calculation was based on the base plate of the adjacent vertebral body caudal to the fractured vertebra (positive angle indicates kyphotic posture);
- segmental scoliosis angle (SSA-1): angle (in the frontal reconstruction) between the cranial plate of the fractured vertebra and the cover plate of the adjacent vertebra on the cranial side and the adjusted segmental scoliosis angle (SSA-2), which is the same as SSA-1 but includes the cranial intervertebral disk. As for SKA measurements of SSA were extended by one segment caudally for bisegmental injuries;
- USS angle (USS): angle between the cranial and caudal pedicle Schanz screws. The mean was calculated for both sides (positive angle indicates kyphotic posture).

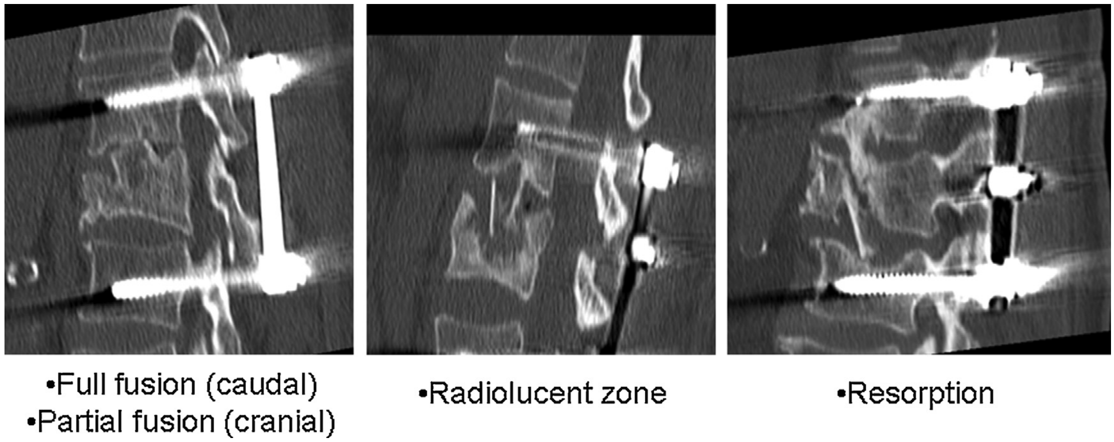

Fig. 1. Figures showing the four types of fusion according to the McAfee method.

Fusion of the anterior bone graft was assessed according to the modified method described by McAfee et al. [7], which has been used in other similar studies [8]. This method leads to the categorization of cranial and caudal fusion as (a) full, (b) partial, (c) lytic zone and (d) graft resorption (Fig. 1). In addition, fusion in the frontal plane was assessed according to the method described by Badke et al. [9]. The bridged segment is divided into several zones and fusion is assessed in each zone individually so that the sum of fusion in all the zones yields an overall assessment of bridging as (a) sufficient, (b) partial or (c) non-sufficient.

2.4. Statistical analysis

Data acquisition and statistical analysis was done with the SPSS software (Release 15; SPSS Inc., Chicago, Illinois). Comparison of the values obtained for the different angles at the two time points was performed by *t*-test for paired specimens, evaluation of their relationship to fusion given normal distribution of data was performed with the Oneway ANOVA for comparison of angle changes across the different fusion groups. Pearson's correlation method was used to determine the correlations of different parameters among themselves. The alpha level was set at 5% for all tests.

3. Results

3.1. Correction loss

The results of statistical testing of the parameters given above are summarized in Table 4. Overall significant changes were found for all angles under investigation except for those in the frontal plane (scoliosis angles), thus confirming correction loss. Changes in the vertebral wedge angle of 4.8° on average were almost twice the magnitude of the angle changes of the USS pedicle Schanz screws at 2.7°. Pearson's correlation analysis showed a statistically significantly high correlation between the angle changes of the pedicle screws on both sides (right to left, $r = 0.9$, $P < 0.001$). Correlation of the changes in SKA-1 and SKA-2 was low ($r = 0.26$, $P = 0.003$). There was no correlation between the correction losses indicated by SKA-1 or SKA-2 and the angle changes of the Schanz screws ($r = 0.08$ and $r = 0.06$, respectively). Likewise, comparison of mono- or bisegmental anterior fusions did not reveal any significant angle changes (*t*-test; VWA: $P = 0.676$, SKA-1: $P = 0.292$, SKA-2: $P = 0.624$, SI: $P = 0.971$). However, angle changes for the USS Schanz screws were significantly higher for bisegmental anterior fusions (monosegmental 2.3°, bisegmental 4.3°, $P = 0.032$).

Table 4
Radiological evaluation immediately after spondylodesis and shortly before explantation of the posterior spondylodesis system (USS).

	After spondylodesis	Before USS explantation	Difference	P
VWA	4.8 (5.1)	6.7 (5.8)	2.1° (3.7)	<0.001
SKA-1	3.5 (8.1)	8.6 (9.2)	4.9° (6.6)	<0.001
SKA-2	−3.0 (9.7)	2.3 (10.3)	4.8° (6.3)	<0.001
SI	0.9 (0.1)	0.8 (0.13)	−0.04 (0.08)	<0.001
SSA-1	0.3 (1.8)	0.4 (2.1)	0° (1.7)	0.805
SSA-2	0.3 (2.1)	0.3 (1.9)	0° (1.9)	0.927
USS right	−1.9 (7.4)	0.9 (7.1)	2.6° (4.2)	<0.001
USS left	−2.0 (7.8)	0.81 (7.9)	2.8° (4.6)	<0.001

Mean and standard deviation in parenthesis.

3.2. Bone fusion of the anterior column

The descriptive results of fusion assessment by the two different methods are shown in Table 5. A mean positive correlation of 0.6 (Pearson's correlation, $P < 0.001$) was found for comparison of the two methods. The results obtained from classification based on the McAfee method indicated poorer quality of consolidation in the caudal region of the bone graft compared with the cranial region.

3.3. Relationship between correction loss and bone fusion

3.3.1. Badke classification

Taking into account all the analyzed angles, no statistically significant differences were found between the 3 groups "sufficient fusion", "partial fusion" and "non-sufficient fusion" (Oneway ANOVA; VWA: $P = 0.321$, SKA-1: $P = 0.064$, SKA-2: $P = 0.950$, SI: $P = 0.381$, SSA-1: $P = 0.538$, SSA-2: $P = 0.389$, USS right: $P = 0.867$, USS left: $P = 0.729$; Fig. 2).

Table 5
Assessment of bone fusion according to the two different classifications.

Badke classification	%	
Sufficient	19.7	
Partial	61.3	
Not sufficient	19	
McAfee fusion	**Cranial (%)**	**Caudal (%)**
Full fusion	64.1	47.2
Partial fusion	20.4	28.9
Radiolucent zone	8.5	16.9
Resorption	7	7

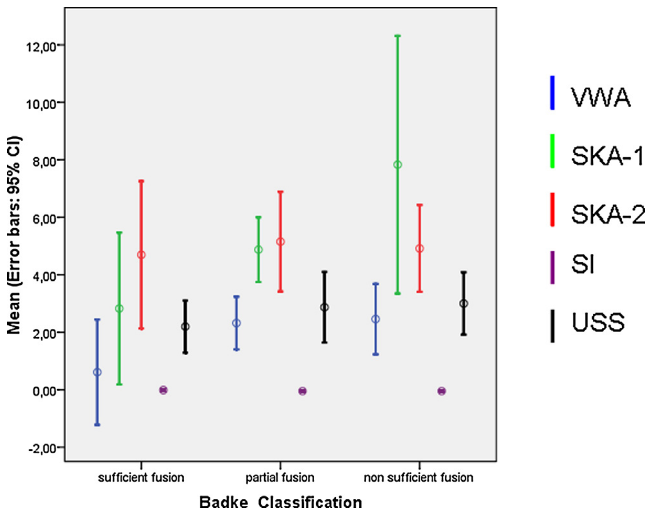

Fig. 2. Schematic representation of angle changes for the three groups arising from the Badke classification. No significant differences. VWA: vertebral wedge angle; SKA-1: segmental kyphotic angle; SKA-2: adjusted segmental kyphotic angle; SI: sagittal index; USS: angle between the cranial and caudal pedicle Schanz screws (mean of both sites).

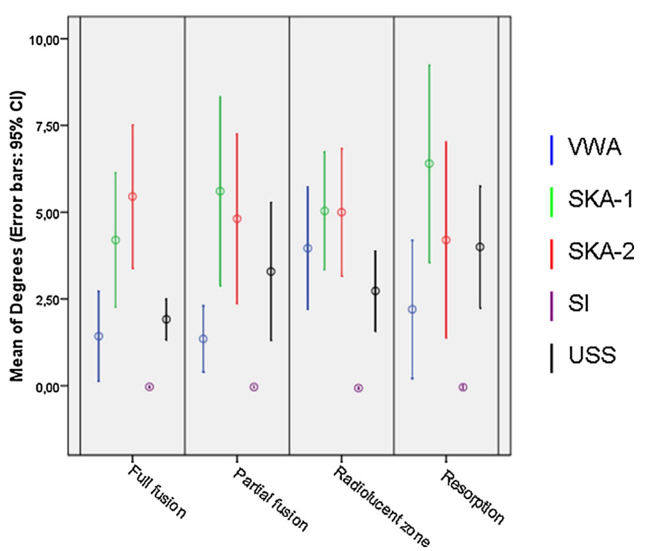

Fig. 3. Schematic representation of angle changes for the four groups arising from the McAfee classification. Only a marginally significant group difference ($P = 0.05$) was found for the vertebral wedge angle of the affected vertebra. VWA: vertebral wedge angle; SKA-1: segmental kyphotic angle; SKA-2: adjusted segmental kyphotic angle; SI: sagittal index; USS: angle between the cranial and caudal pedicle Schanz screws (mean of both sites).

3.3.2. McAfee classification

For the correlation of consolidation and correction loss the lowest value for cranial or caudal fusion was analyzed for each graft. Only a marginally significant group difference ($P = 0.05$) was found for the VWA of the affected vertebra in comparison of the four groups of the McAfee classification (full fusion, partial fusion, radiolucent zone, resorption). All other parameter changes were not significant in inter-group comparison (Oneway ANOVA; SKA-1: $P = 0.736$, SKA-2: $P = 0.964$, SI: $P = 0.472$, SSA-1: $P = 0.486$, SSA-2: $P = 0.577$, USS right: $P = 0.415$, USS left: $P = 0.387$; Fig. 3).

4. Discussion

The evidence from the study reported here showed that even additional antero-posterior stabilization will not achieve total retention of the immediate postoperative reduction. Likewise, complete fusion of the anterior column was only seen on the CT scans in a small proportion of patients. Correction loss in patients with poorer quality fusion was however not significantly greater than in patients with a good radiological outcome.

Several investigations have confirmed that an almost complete loss of intraoperative corrective gain is to be expected if posterior instrumentation is used in isolation [10]. The cause of these high correction losses has been identified as a lack of anterior column reconstruction since this is the region of the thoracolumbar junction that carries more than 80% of the total load. If the integrity of this load-bearing region is not restored, posttraumatic kyphosis will occur at the latest when the posterior implant is removed, whereby, depending on its severity, kyphosis is often associated with clinical pathology in the long-term. Apart from incongruency of the small vertebral joints, there is also the risk of spinal canal stenosis with resulting myelopathy and secondary neurological deficits due to progressive exacerbation of kyphosis [11]. An alternative to isolated posterior instrumentation has been practised since the end of the 1980s in the form of a combined procedure with antero-posterior stabilization of the injured spinal segment [12]. The biomechanical superiority of a combined antero-posterior approach has been substantiated in several experimental studies [13,14]. Despite the potentially higher surgical risks [15,16], reconstruction of the anterior column has increasingly gained in importance in the surgical management of unstable vertebral body fractures at the thoracolumbar junction. The use of autogenous graft from the iliac crest, which is far superior to any other material in terms of its biological properties [17], has become standard procedure, whereupon vertebral body substitutes appear to be more advantageous than autologous iliac crest grafts [18].

Furthermore, bone graft stability under various types of load is a key factor for anterior vertebral fusion and has a critical effect on the stability of the fusion and the overall outcome [19,20]. Graft size can have a decisive influence and this underlines the importance of graft stability and therefore the maintenance of the sagittal correction.

The durability of the sagittal correction also may have been affected by the number of previous surgeries. The patients with correction loss had an average of 4 surgeries compared with 2.7 surgeries in those without loss of correction [21].

4.1. Limitations of the study

This study evaluated correction loss with the posterior implant in situ. It has to be assumed that additional correction loss occurs after explantation of the posterior fixator. At our institution radiological evaluation of patients after material explantation relied solely on plain radiographs. Comparison of correction loss as evidenced on the CT scans and radiographs would have made little sense in most cases because of the different projections. Although earlier studies [22] have found a statistically good correlation between the two imaging methods, a proven discrepancy of up to 6° for the evaluation of kyphosis might lead to misinterpretation of the results.

Fusion assessment was based on a “clinical 64 MD-CT”. More recent animal experimentation [23] has shown however that higher resolution investigation, e.g. “high-resolution peripheral quantitative CT (HR-CT)”, yields different findings for osseous integration. Consequently, it might be assumed that a correlation of correction loss with HR-CT findings would lead to different conclusions. The sample size limit, however, prohibits in vivo use of this method in evaluation of the human spine [23].

5. Conclusion

Correction loss after stabilization of vertebral body fracture with autogenous bone graft is unavoidable even with posterior angular stability. The importance of radiologically visible fusion is however questionable since the extent of fusion only has a minimal effect on correction loss.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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